

**Section I (Pending Claims)**

The pending claims 1-116 of the application are set out below.

1. (Original) Large-area, single-crystal semi-insulating gallium nitride.
2. (Original) Gallium nitride according to claim 1, doped with a transition metal dopant species to compensate residual donor species in the gallium nitride, wherein the concentration of transition metal dopant species is sufficient to render the gallium nitride semi-insulating.
3. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises at least one transition metal selected from the group consisting of Cr, Mo, W, Mn, Re, Fe, Ru, Os, Co, Rh, Ir, Ni, Pd, Pt, Cu, Ag, Au, Zn, Cd and Hg.
4. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises at least one transition metal selected from the group consisting of Mn, Fe, Co, Ni and Cu.
5. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises manganese.
6. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises cobalt.
7. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises nickel.
8. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises copper.

Best Available Copy

9. (Original) Gallium nitride according to claim 2, wherein the transition metal dopant species comprises iron.

10. (Original) Gallium nitride according to claim 1, as formed by hydride vapor phase epitaxy (HVPE).

11. (Original) Gallium nitride according to claim 1, with a thickness in a range of from about 50 micrometers to about 5 centimeters.

12. (Original) Gallium nitride according to claim 1, in the form of a boule.

13. (Original) Gallium nitride according to claim 12, wherein the boule has a thickness in a range of from about 300 micrometers to about 5 centimeters.

14. (Original) Gallium nitride according to claim 1, which is free-standing.

15. (Original) Gallium nitride according to claim 14, having a diameter of at least 50 millimeters, and a thickness of at least 300 micrometers.

16. (Original) Gallium nitride according to claim 15, wherein the thickness is in a range of from 300 micrometers to 5 centimeters.

17. (Original) Gallium nitride according to claim 1, having a resistivity greater than about  $10^2 \Omega\text{-cm}$ , at 25°C.

18. (Original) Gallium nitride according to claim 1, having a resistivity greater than about  $10^5 \Omega\text{-cm}$ , at 25°C.

19. (Original) Gallium nitride according to claim 1, having a resistivity greater than about  $10^2 \Omega\text{-cm}$ , at  $200^\circ\text{C}$ .
20. (Original) Gallium nitride according to claim 1, having a resistivity greater than about  $10^5 \Omega\text{-cm}$ , at  $200^\circ\text{C}$ .
21. (Original) Gallium nitride according to claim 1, having a resistivity greater than about  $10^5 \Omega\text{-cm}$ , at  $300^\circ\text{C}$ .
22. (Original) Gallium nitride according to claim 1, wherein unintentional impurities are less than  $5 \times 10^{17} \text{ cm}^{-3}$ .
23. (Original) Gallium nitride according to claim 1, wherein unintentional impurities are less than  $1 \times 10^{17} \text{ cm}^{-3}$ .
24. (Original) Gallium nitride according to claim 1, wherein unintentional impurities are less than  $5 \times 10^{16} \text{ cm}^{-3}$ .
25. (Original) Gallium nitride according to claim 1, wherein unintentional impurities are less than  $1 \times 10^{16} \text{ cm}^{-3}$ .
26. (Original) Gallium nitride according to claim 1, having a dislocation defect density not exceeding  $10^7 \text{ defects /cm}^2$ .
27. (Original) Gallium nitride according to claim 1, having a dislocation defect density not exceeding  $10^6 \text{ defects /cm}^2$ .

28. (Original) Gallium nitride according to claim 1, having a dislocation defect density not exceeding  $10^5$  defects/cm<sup>2</sup>.
29. (Original) Gallium nitride according to claim 2, comprising background impurities including silicon and oxygen, wherein said transition metal dopant species comprises iron, and said iron has a concentration that is greater than total concentration of said silicon and said oxygen.
30. (Original) Gallium nitride according to claim 2, wherein said transition metal dopant species comprises iron, at a concentration in a range of from about  $3 \times 10^{16}$  atoms/cm<sup>3</sup> to about  $7 \times 10^{17}$  atoms/cm<sup>3</sup>, as determined by SIMS.
31. (Original) Gallium nitride according to claim 1, doped with a dopant species to compensate residual donor species in the gallium nitride, wherein the dopant species has an activation energy greater than 0.35 eV.
32. (Original) Gallium nitride according to claim 1, doped with a dopant species to compensate residual donor species in the gallium nitride, wherein the dopant species has an activation energy greater than 0.50 eV.
33. (Original) Gallium nitride according to claim 1, doped with a dopant species to compensate residual donor species in the gallium nitride, wherein the dopant species has an activation energy greater than 0.75 eV.
34. (Original) Gallium nitride according to claim 1, doped with a transition metal dopant species having an activation energy greater than 0.35 eV.
35. (Original) Gallium nitride according to claim 1, including microelectronic circuitry fabricated thereon and/or therein, wherein the gallium nitride is semi-insulating in an operating temperature regime of said microelectronic circuitry.

36. (Original) Gallium nitride according to claim 1, having electronic circuitry fabricated thereon and/or therewithin.

37. (Original) An electronic device structure, comprising gallium nitride as in claim 1, and an electronic device fabricated thereon and/or therewithin.

38. (Original) The electronic device structure of claim 37, wherein the electronic device comprises a high electron mobility transistor (HEMT).

39. (Original) The electronic device structure of claim 37, wherein the electronic device comprises a monolithic microwave integrated circuit (MMIC).

40. (Original) The electronic device structure of claim 37, wherein said gallium nitride is on a conductive substrate.

41. (Original) The electronic device structure of claim 40, wherein the electronic device comprises a high power rectifier.

42. (Withdrawn) A method of forming large area, semi-insulating gallium nitride, comprising growing gallium nitride material by a growth process, and during the growth process, doping the growing gallium nitride with a dopant species that is effective to compensate residual donor species in the gallium nitride, wherein the concentration of the dopant species is sufficient to render the gallium nitride semi-insulating.

43. (Withdrawn) The method of claim 42, wherein the dopant species comprises at least one transition metal selected from the group consisting of Cr, Mo, W, Mn, Re, Fe, Ru, Os, Co, Rh, Ir, Ni, Pd, Pt, Cu, Ag, Au, Zn, Cd and Hg.

Best Available Copy

44. (Withdrawn) The method of claim 42, wherein the dopant species comprises at least one transition metal selected from the group consisting of Mn, Fe, Co, Ni and Cu.
45. (Withdrawn) The method of claim 42, wherein the dopant species comprises manganese.
46. (Withdrawn) The method of claim 42, wherein the dopant species comprises cobalt.
47. (Withdrawn) The method of claim 42, wherein the dopant species comprises nickel.
48. (Withdrawn) The method of claim 42, wherein the dopant species comprises copper.
49. (Withdrawn) The method of claim 42, wherein the dopant species comprises iron.
50. (Withdrawn) The method of claim 42, wherein the gallium nitride contains background impurities including silicon and oxygen, wherein said dopant species comprises iron, and said iron has a concentration that is greater than total concentration of said silicon and said oxygen.
51. (Withdrawn) The method of claim 42, wherein said dopant species comprises iron, and the growth process is conducted to provide the gallium nitride with an iron concentration in a range of from about  $3 \times 10^{16}$  atoms/cm<sup>3</sup> to about  $7 \times 10^{17}$  atoms/cm<sup>3</sup>, as determined by SIMS.
52. (Withdrawn) The method of claim 42, wherein the growth process comprises hydride vapor phase epitaxy (HVPE).
53. (Withdrawn) The method of claim 42, wherein the gallium nitride has a resistivity greater than about  $10^2 \Omega\text{-cm}$ , at 25°C.

54. (Withdrawn) The method of claim 42, wherein the gallium nitride has a resistivity greater than about  $10^5 \Omega\text{-cm}$ , at  $25^\circ\text{C}$ .

55. (Withdrawn) The method of claim 42, wherein the gallium nitride has a resistivity greater than about  $10^2 \Omega\text{-cm}$ , at  $200^\circ\text{C}$ .

56. (Withdrawn) The method of claim 42, wherein the gallium nitride has a resistivity greater than about  $10^5 \Omega\text{-cm}$ , at  $200^\circ\text{C}$ .

57. (Withdrawn) The method of claim 42, wherein the gallium nitride has a resistivity greater than about  $10^5 \Omega\text{-cm}$ , at  $300^\circ\text{C}$ .

58. (Withdrawn) The method of claim 42, wherein the dopant species has an activation energy greater than 0.35 eV.

59. (Withdrawn) The method of claim 42, wherein the dopant species has an activation energy greater than 0.50 eV.

60. (Withdrawn) The method of claim 42, wherein the dopant species has an activation energy greater than 0.75 eV.

61. (Withdrawn) The method of claim 42, wherein unintentional impurities of the gallium nitride are less than  $5 \times 10^{17} \text{ cm}^{-3}$ .

62. (Withdrawn) The method of claim 42, wherein unintentional impurities of the gallium nitride are less than  $1 \times 10^{17} \text{ cm}^{-3}$ .

63. (Withdrawn) The method of claim 42, wherein unintentional impurities of the gallium nitride are less than  $5 \times 10^{16} \text{ cm}^{-3}$ .

64. (Withdrawn) The method of claim 42, wherein unintentional impurities of the gallium nitride are less than  $1 \times 10^{16} \text{ cm}^{-3}$ .

65. (Withdrawn) The method of claim 42, wherein the gallium nitride has a dislocation density not exceeding  $10^7 \text{ defects /cm}^2$ .

66. (Withdrawn) The method of claim 42, wherein the gallium nitride has a dislocation density not exceeding  $10^6 \text{ defects /cm}^2$ .

67. (Withdrawn) The method of claim 42, wherein the gallium nitride has a dislocation density not exceeding  $10^5 \text{ defects /cm}^2$ .

68. (Withdrawn) The method of claim 42, wherein the gallium nitride produced by the growth process is free-standing.

69. (Withdrawn) The method of claim 68, wherein the gallium nitride has a diameter of at least 50 millimeters, and a thickness of at least 300 micrometers.

70. (Withdrawn) The method of claim 69, wherein the gallium nitride has a thickness in a range of from 300 micrometers to 5 centimeters.

71. (Withdrawn) The method of claim 42, comprising growing the gallium nitride to form a boule by an HVPE growth process.



Not Available Copy

72. (Withdrawn) The method of claim 42, further comprising fabricating electronic circuitry on and/or within the gallium nitride.

73. (Withdrawn) The method of claim 42, further comprising fabricating an electronic device on and/or within the gallium nitride.

74. (Withdrawn) The method of claim 42, comprising forming said gallium nitride on a conductive substrate.

75. (Withdrawn) The method of claim 42, wherein said growth process comprises growing gallium nitride on a seed crystal.

76. (Withdrawn) The method of claim 75, wherein the seed crystal comprises a free-standing GaN seed crystal.

77. (Withdrawn) The method of claim 75, wherein said growth process comprises growing gallium nitride on a conductive seed crystal, said method further comprising removing the conductive seed crystal from the gallium nitride produced by the growth process.

78. (Withdrawn) The method of claim 75, wherein the seed crystal comprises a semi-insulating seed crystal.

79. (Withdrawn) The method of claim 75, wherein the seed crystal comprises a seed crystal having a defect density of less than  $10^7$  defects/cm<sup>2</sup>.

80. (Withdrawn) The method of claim 42, wherein the growth process comprises reacting hydrochloric acid (HCl) with metallic gallium to form gaseous GaCl, and reacting the gaseous GaCl with NH<sub>3</sub> to form the large area, semi-insulating gallium nitride.

81. (Withdrawn) The method of claim 42, wherein the growth process comprises reacting gallium chloride with ammonia to form the large area, semi-insulating gallium nitride.

82. (Withdrawn) The method of claim 42, wherein the growth process comprises an HVPE growth process, and the HVPE growth process is carried out to produce gallium nitride with a dislocation defect density not exceeding  $10^7$  defects/cm<sup>2</sup>.

83. (Withdrawn) The method of claim 42, wherein the growth process comprises an HVPE growth process, and the HVPE growth process is carried out to produce gallium nitride with a dislocation defect density not exceeding  $10^6$  defects/cm<sup>2</sup>.

84. (Withdrawn) The method of claim 42, wherein the growth process comprises a multiple-stage HVPE growth process.

85. (Withdrawn) The method of claim 42, wherein the growth process comprises an HVPE growth process, wherein reactants NH<sub>3</sub> and HCl are supplied in a ratio NH<sub>3</sub>/HCl that is in a range of from about 2 to about 40.

86. (Withdrawn) The method of claim 42, wherein the growth process comprises an HVPE growth process, wherein the HVPE growth process is carried out with growth rate in a range of from about 50 to about 250 micrometers per hour, growth temperature in a range of from about 950 to about 1150°C, pressure in a range of from about 25 to about 760 torr, and V/III ratio in a range of from about 2 to about 50.

87. (Withdrawn) The method of claim 42, wherein the dopant species comprises a transition metal, and the growth process comprises mixing the transition metal with a gallium source, thereby forming a solution of the transition metal impurity in gallium.

88. (Withdrawn) The method of claim 42, wherein the growth process comprises an HVPE growth process and the dopant species comprises a transition metal, wherein the HVPE growth process comprises reacting the transition metal dopant species with HCl to convert transition metal to gaseous metal chloride.

89. (Withdrawn) The method of claim 42, wherein the growth process comprises an HVPE growth process including reacting hydrochloric acid with metallic gallium to form gaseous gallium chloride, and reacting the gaseous gallium chloride with ammonia to form said large-area, semi-insulating gallium nitride.

90. (Withdrawn) The method of claim 89, wherein the step of reacting the gaseous gallium chloride with ammonia is conducted in a growth zone, and the dopant species comprises a transition metal in the growth zone in a form in which the transition metal is incorporated in the growing gallium nitride.

91. (Withdrawn) The method of claim 42, wherein the growth process comprises reacting the dopant species with HCl to convert the dopant species into a gaseous chloride.

92. (Withdrawn) The method of claim 42, wherein the growth process comprises providing a transition metal chloride in a growth zone in which the growth process is conducted.

93. (Withdrawn) The method of claim 42, wherein the dopant species is derived from a transition metal precursor that is introduced to the growth process.

94. (Withdrawn) The method of claim 93, wherein the transition metal precursor comprises a metalorganic precursor.

95. (Withdrawn) The method of claim 94, wherein the metalorganic precursor comprises a bis(cyclopentadienyl) compound of the transition metal.

96. (Withdrawn) The method of claim 95, wherein the transition metal comprises a metal selected from the group consisting of iron, manganese, cobalt, nickel, chromium and copper.

97. (Withdrawn) The method of claim 42, wherein the dopant species is delivered by bubbler delivery to the growth process.

98. (Withdrawn) The method of claim 42, wherein the growth process comprises growing the large-area, semi-insulating gallium nitride on a heteroepitaxial substrate.

99. (Withdrawn) The method of claim 98, wherein the heteroepitaxial substrate comprises a material selected from the group consisting of sapphire and silicon carbide.

100. (Withdrawn) The method of claim 98, further comprising removing the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, to yield free-standing large-area, semi-insulating gallium nitride.

101. (Withdrawn) The method of claim 100, wherein removal of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, comprises a step selected from the group consisting of grinding, chemical etching, dry etching, parting techniques and liftoff techniques.

102. (Withdrawn) The method of claim 100, wherein removal of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, comprises reactive ion etching.

103. (Withdrawn) The method of claim 100, wherein removal of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, comprises in situ removal of the heteroepitaxial

substrate at or in the vicinity of growth temperature of the large-area, semi-insulating gallium nitride.

104. (Withdrawn) The method of claim 100, wherein removal of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, comprises fracturing the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride.

105. (Withdrawn) The method of claim 100, wherein removal of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, comprises use of a parting layer between the heteroepitaxial substrate and the large-area, semi-insulating gallium nitride.

106. (Withdrawn) The method of claim 100, wherein removal of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride, comprises impinging energy on an interface between the heteroepitaxial substrate and the large-area, semi-insulating gallium nitride, to weaken the interface and cause separation of the heteroepitaxial substrate from the large-area, semi-insulating gallium nitride.

107. (Withdrawn) The method of claim 42, wherein the large area, semi-insulating gallium nitride is formed as a boule, further comprising forming wafer blanks from said boule.

108. (Withdrawn) The method of claim 107, wherein the step of forming wafer blanks from said boule comprises sawing wafer blanks from the boule.

109. (Withdrawn) The method of claim 107, further comprising at least one processing step selected from the group consisting of lapping, polishing and planarization operations.

110. (Withdrawn) The method of claim 109, wherein the wafer blank after said at least one processing step has a dislocation defect level on a surface thereof that is below  $10^6$  defects  $\text{cm}^{-2}$ .

111. (Withdrawn) The method of claim 42, wherein said dopant species comprises iron, and said large-area, semi-insulating gallium nitride has iron doped therein at concentration in a range of from about  $3 \times 10^{16}$  atoms/ $\text{cm}^3$  to about  $7 \times 10^{17}$  atoms/ $\text{cm}^3$ , as determined by SIMS.

112. (Withdrawn) The method of claim 42, further comprising fabricating a microelectronic circuitry on and/or in the gallium nitride, wherein the gallium nitride is semi-insulating in an operating temperature regime of said microelectronic circuitry.

113. (Withdrawn) The method of claim 42, further comprising using the large-area, semi-insulating gallium nitride as a substrate for an electronic device.

114. (Withdrawn) A method of forming large area, semi-insulating gallium nitride, comprising growing gallium nitride material by a growth process in which donor species in the growing gallium nitride are compensated, by introducing into the growing gallium nitride one or more deep acceptor species in a sufficient amount to compensate the donor species and produce semi-insulating GaN material.

115. (Withdrawn) The method of claim 114, further comprising maintaining BIC below BIL during the growth process.

116. (Withdrawn) The method of claim 114, wherein said acceptor species comprises iron, and BIC is below  $5.0 \times 10^{17} \text{cm}^{-3}$ .

## Section II (Remarks)

It is noted by way of preface to the ensuing discussion that a Supplemental Response to the November 30, 2004 Office Action was filed on May 6, 2005 in this application, to provide additional distinguishing remarks in respect of the cited Heitz et al., Heikman et al. and Cuomo et al. references, as a supplement to the Response filed on February 28, 2005 to the November 30, 2004 Office Action.

This Supplemental Response, however, does not appear to have been considered by the examiner. It is noted in this respect that the Office Action Summary (PTOL-326) states in box no. 1 that it is "[r]esponsive to communication(s) filed on 28 February 2005" and the "DETAILED ACTION/Response to Arguments" at page 2 of the Office Action states in paragraph 1 that "Applicant's arguments filed February 28, 2005 have been fully considered, but they are not persuasive." The subsequent statements of rejection and discussion in the Office Action further reflect that the distinguishing remarks of the May 6, 2005 Supplemental Response were not before the examiner at the time the May 9, 2005 Office Action was formulated.

The Image File Wrapper at the USPTO website indicates that the Supplemental Response of May 6, 2005 was entered in the file (see Appendix A hereof, showing the IFW record of this application on the USPTO website, as visited on September 9, 2005).

Accordingly, to expedite the prosecution this application, the substance of the May 6, 2005 Supplemental Response is incorporated herein, as applied to the grounds of rejection stated in the May 9, 2005 Office Action.

### **The §102 and §103 Rejections of Claims 1-41, and Traversal Thereof**

In the May 9, 2005 Office Action, the Examiner rejected claims 1-41 on reference grounds, including:

a rejection of Claims 1-10 under 35 U.S.C. §102(b) as being anticipated by **Heltz et al., Excited States of Fe<sup>3+</sup> in GaN, PHYSICAL REVIEW B., Vol. 55, No. 7, pp. 4382-4387 (Feb. 15, 1997)** (hereinafter "Heitz");

Available Copy

a rejection of Claims 11-38 under 35 U.S.C. §103(a) as being obvious over **Heitz**;

a rejection of Claim 30 under 35 U.S.C. §103(a) as being obvious over **Heitz** in view of **Heikman et al. Growth of Fe Doped Semi-Insulating GaN by Metalorganic Chemical Vapor Deposition**, APPLIED PHYSICS LETTERS, Vol. 81, No. 3, pp. 439-441 (July 15, 2002) (hereinafter "Heikman"); and

a rejection of Claims 14 and 39-41 under 35 U.S.C. §103(a) as being obvious over **Heitz** in view of **Cuomo et al.**, U.S. Patent No. 6,692,586 (hereinafter "Cuomo").

These rejections are traversed.

Reconsideration of the patentability of claims 1-41 is requested, based on the following remarks.

**Patentability of Claims 1-41 over the Heitz et al., Heikman et al. and Cuomo et al. References as Applied in the §102 and §103 Rejections of Claims 1-41**

In paragraph 2 at page 2 of the May 9, 2005 Office Action, the examiner has contended that the feature of "having a diameter of at least 25 millimeters, or in the case of square or rectangular wafers, a diagonal dimension of at least 25 mm" relied on by the applicants "are not recited in the rejected claim(s)," citing *In re Van Geun*, 988 F.2d 1181, 26 USPQ 2d 1057 (Fed. Cir. 1993) for the principle that although claims are interpreted in light of the specification, limitations are not read into the claims.

Applicants concur with the examiner's statement of the law concerning reading limitations of the specification into the claims. This is not in dispute - applicants are in fact not attempting to read in additional limitations, but rather to accord the claim language its expressly defined meaning. As was stated by United States Court of Appeals for the Federal Circuit in *Edward H. Phillips v. AWH Corp.*, decided July 12, 2005:

"our cases recognize that the specification may reveal a special definition given to a claim term by the patentee...[i]n such cases, the inventor's lexicography governs" (citing *CCS Fitness, Inc. v. Brunswick Corp.*, 288 F3d 1359, 1366 (Fed. Cir. 2002)).



See also *Multiform Dessicants Inc. v. Medzam Ltd.*, 133 F.3d 1473, 1477, 45 USPQ2d 1429, 1432 (Fed. Cir. 1998) and M.P.E.P. 2111.02 ("[I]t is well-established that a patent applicant may be his own lexicographer, so long as (1) the meaning assigned to a term is not repugnant to its well-known usage, and (2) the special meaning is "sufficiently clear in the specification that any departure from common usage would be so understood by a person of experience in the field of the invention").

The term "large-area" is defined in the instant specification at page 6, paragraph [0022]:

**"As used herein, the term 'large area' in reference to the GaN material means that such material has a diameter of at least 25 millimeters, or in the case of square or rectangular wafers, a diagonal dimension of at least 25 millimeters. The thickness dimension desirably is at least 300 micrometers, e.g., a thickness in a range of from about 300 micrometers to about 5 centimeters or more. These dimensions are in reference to the wafers as formed from the original crystal growth single wafers or from boules by steps including initial crystal growth to form the boule or ingot article, followed by rounding, sizing, slicing, lapping, polishing, etc. as necessary to produce wafers having surfaces suitable for epitaxial growth thereon."**

Consistent with the applicable governing precedent declared by the CAFC, the term "large-area" as used in applicants' claims has a clear and express meaning.

Accordingly, concerning the rejection of claims 1-10 on §102 grounds, based on Heitz et al., it is to be noted that claim 1, from which claims 2-10 depend, recites:

**"Large-area, single-crystal semi-insulating gallium nitride."**

in which the term "large-area" means a diameter of at least 25 mm, or in the case of square or rectangular wafers, a diagonal dimension of at least 25 mm, consistent with the definition at page 6, paragraph [0022], above quoted.

As related in the background section of the present application, such "large area" single crystal, insulating gallium nitride has not been achieved by the prior art:

"[0005] U.S. Patent 6,273,948 issued to Porowski et al. describes a method of fabricating highly resistive GaN bulk crystals, by crystallization from a solution of atomic nitrogen in a molten mixture of gallium and Group II metal such as beryllium or calcium, under high pressure of 0.5-2.0 GPa and high temperature of 1300-1700° C. Resistivity of  $1 \times 10^4$  to  $1 \times 10^8$  ohm-centimeter (ohm-cm) was achieved. However, the crystal obtained from the process was about 1 cm in size, whereas most commercial electronic applications require a substrate size of at least about 2 inches ( $> 5$  cm) diameter.

"[0006] U.S. Patent 5,686,738 (Moustakas), U.S. Patent 6,544,867 (Webb et al.), U.S. Patent 6,261,931 (Keller et al.) and U.S. Patent Application 2002/0096692 A1 (Nakamura et al.), disclose various methods of making semi-insulating GaN films on a foreign substrate. All of these approaches are susceptible to TE mismatch issues, and the resultant Boeing, cracking and small feature fabrication difficulties discussed above, and none of such approaches has yielded a commercially viable, large-area single-crystal semi-insulating gallium nitride material."

The foregoing references of the above-quoted background text of the application are of interest, since the references identified in such passage are all directed to formation of high resistivity GaN, and all of these references were published after the February 15, 1997 publication date of Heitz et al. (Porowski published on December 10, 1998; Moustakas was issued November 11, 1997; Webb et al. issued on April 8, 2003; Keller et al. issued on July 17, 2001; and Nakamura et al. was published on July 25, 2002), yet none of the authors of these references was able to make a large area, semi-insulating, single-crystal GaN material, and these references underscore the fact that large-area, semi-insulating, single-crystal GaN material is not in any way disclosed or suggested by Heitz et al.

Heitz et al. describes GaN layers that are epitaxially grown on (0001) sapphire, but there is no disclosure or any suggestion whatsoever of the size of the crystal, merely a mention that the semi-insulating GaN crystal was 38  $\mu$ m thick (since, as disclosed in paragraph [0031] of the present application, "[T]he thickness dimension [of applicants' invention] desirably is at least 300 micrometers," this is hardly suggestive of any material of the present invention). Additionally, there is no disclosure in Heitz et al. that identifies the GaN material of such reference as being single crystal in character.

Instead, the GaN material of the Heitz et al. reference is ambiguously and indefinitely characterized.

There is no disclosure of bulk resistivity of the GaN material in Heitz et al. Heitz et al. instead is focused on photoluminescence excitation results for iron (3+) luminescence in hexagonal GaN, but even here, Heitz et al. refers to crystal material as having semi-insulating character on the basis of an electron paramagnetic resonance (EPR) signal that is observable in the dark (see Heitz et al. at the page 4382, second column, last paragraph ("[T]he Fe<sup>3+</sup> EPR signal can be observed in the dark for the crystals 2 and 3 *confirming the semi-insulating character of these two samples*"-emphasis added)).

In the sentence bridging pages 4382 and 4383 of the article, and in the following sentence on page 4383 of the article, Heitz et al. state that in addition to the luminescence observed attributable to the tri-positive cation of iron, luminescence was attributed to Cr<sup>4+</sup> and Ti<sup>2+</sup> as well.

In the results section of the article, on page 4383, the authors note that iron "is a general contamination of the crystals" used in their work, and that the luminescence attributed to Fe<sup>3+</sup> "is representative of all the samples investigated" (including crystal characterized as n-type).

Heitz et al. ignores the basic standard that semi-insulators are characterized by bulk resistivity, and not a luminescent signature. Heitz et al. contains no resistance measurements, no potential gradient determinations, and no rigorous basis for characterizing any GaN material as being semi-insulative in character. Further, the luminescence that is the sole basis of the semi-insulative characterization, is attributed to general contamination of the crystals by iron, chromium and titanium, contaminants that are conceded by the authors to be present in all crystal material considered by them, including n-type crystal material.

Reduce to its essence, the proper inquiry concerning the relevance of Heitz et al. is, if photoluminescence is the indicator specified by Heitz et al. for semi-insulative material, and all samples investigated by Heitz et al. exhibit such luminescence, including n-type crystal material, then such n-type crystal material must be semi-insulative material according to the criterion of Heitz et al. One skilled in the art, however, knows that n-type crystal material is NOT semi-insulative material, and that n-type material and semi-insulative material reside in different bulk resistivity regimes that demarcate them as n-type or semi-insulative. Heitz et al. therefore is seen to be confusing and contrary to common sense.

It is well settled that an anticipation rejection cannot be predicated on an ambiguous reference. *In re Turlay*, 304 F.2d 893, 899, 134 USPQ 355, 360 (CCPA 1962).

The character of applicant's claimed material as semi-insulative is fully clear from the definition of such term in paragraph [0024] of the present application:

[0024] As used herein, the term "semi-insulating" in reference to the semi-insulating GaN material of the invention means that such material has a resistivity > 100 ohm-centimeters ( $\Omega$ -cm) at room temperature ( $\sim 25^\circ\text{C}$ ). In one embodiment, the GaN material of the invention may have a resistivity >  $10^1 \Omega$ -cm at  $200^\circ\text{C}$ . In another embodiment, the semi-insulating GaN material may have a resistivity >  $10^5 \Omega$ -cm at room temperature. More preferably, the semi-insulating GaN material has a resistivity >  $10^5 \Omega$ -cm at  $200^\circ\text{C}$ , and most preferably the semi-insulating GaN material has a resistivity >  $10^5 \Omega$ -cm at  $300^\circ\text{C}$ . Such values of resistivity are determined by four point probing techniques (van der Pauw contact geometry) as a function of temperature. In instances where the GaN material, e.g., as a free-standing substrate article, has microelectronic circuitry fabricated on and/or within such substrate, the GaN material of the invention has a semi-insulating character in the operating temperature regime of such microelectronic circuitry. The term "within" in such context refers to circuitry in which the substrate forms a part of the device, e.g., wherein the substrate is subjected to an implantation process to form implanted device region(s) in the substrate.

Thus, the contention that Heitz et al. anticipates the subject matter of claims 1-10 is without substantive basis, since (1) Heitz et al. does not teach or suggest large-area gallium nitride, (2) Heitz et al. does not provide any rigorous determination of semi-insulating character since the photoluminescence characterization results in a mischaracterization of n-type material as semi-insulating, (3) no resistivity information or data is given for any of the materials tested by the authors, and (4) there is no mention anywhere in Heitz et al. of "single crystal" GaN material.

Additional basis of distinction is present in claims 5-8, which recite manganese, cobalt, nickel and copper, respectively. There is no mention of such species in Heitz et al. as dopants for GaN.<sup>1</sup>

It is fundamental law that anticipation under §102 requires the presence in a single reference of each and every element of the claimed invention, arranged as in the claim. *Lindemann Maschinenfabrik GmbH v. American Hoist & Derrick Co.*, 221 USPQ 481, 485 (Fed. Cir. 1984); *Verdegal Bros. Inc. v. Union Oil Co.*, 814 F2d 628, 631, 2 USPQ2d 1051, 1053 (Fed. Cir. 1986), cert. denied, 484 U.S. 827 (1987). In the present case, Heitz et al. does not disclose each and every element of applicants' claimed invention, as recited in applicants' claims 1-10. The stated basis of rejection therefore cannot stand.

It therefore is requested that the examiner reconsider the subject matter of claims 1-10 in light of the foregoing remarks, and correspondingly withdraw the rejection of claims 1-10 based on Heitz et al.

The same distinguishing remarks as set out above are apposite to the rejection of claims 11-13, 15-29 and 31-38 under §103 as being obvious over Heitz et al. It again is pointed out that (1) Heitz et al. does not teach or suggest large-area gallium nitride, (2) Heitz et al. does not provide any rigorous determination of semi-insulating character since the photoluminescence characterization results in a mischaracterization of n-type material as semi-insulating, (3) no resistivity information or data is given for any of the materials tested by the authors, and (4) there is no mention anywhere in Heitz et al. of "single crystal" GaN material.

Accordingly, since claims 11-13, 15-29 and 31-38 require "large-area", "single crystal" and "semi-insulating" gallium nitride, such claims patently distinguish over Heitz et al. and are otherwise in condition for allowance.

Additional basis of patentable distinction is present in the claims. Heitz et al. teaches a "crystal 3" material that is 38 micrometers thick, but contains no teaching or suggestion of any higher thickness of such "crystal 3" material. Accordingly, there is no derivative basis in Heitz et al. for a thickness in a range of from about 50 micrometers to about 5 cm, as recited in claim 11, or a thickness of from about 300 micrometers to about 5 cm, as recited in claim 13. The same is true for claim 15, which

<sup>1</sup> It is noted that Heitz, et al. discloses manganese, but in zinc sulfide, not GaN; nickel is discussed in connection with zinc sulfide and cadmium sulfide, but not in connection with GaN; copper is mentioned in connection with II-VI semiconductors, but not in connection with III-V semiconductors such as GaN.

recites a thickness of at least 300 micrometers, and additionally has a diameter of at least 50 mm, for which there is no described or suggestive basis in Heitz et al., and it is also true for claim 16, reciting a thickness in a range of from 300 micrometers to 5 cm.

Further, the resistivity values recited in claim as 17-21 have no derivative basis in Heitz et al., since Heitz et al. fail to disclose any resistivity values, instead focusing on PLE spectra, with the accompanying ambiguity and indefiniteness issues discussed hereinabove. There is correspondingly no basis in Heitz et al. for the impurity concentrations recited in claim 22-25, the defect density levels recited in claims 26-28, or the silicon-oxygen-iron recital of claim 29.

Claims 31-38 likewise have no derivative basis in the Heitz et al. teachings; the gallium nitride recited in (dependent) claims 31-34 is gallium nitride according to claim 1, which Heitz et al. fails to disclose (see preceding discussion).

Additionally, Heitz et al. does not disclose fabrication of any microelectronic device or in the materials described in such reference - although there is mention in the background portion of the article of Group-III nitride-based device structures, there is no teaching or suggestion that the specific GaN material described by Heitz et al. is suitable for specific devices. Instead, the Heitz et al. article is simply a report on photoluminescence excitation investigations of the hexagonal GaN samples, and Heitz et al. contains no instructions or direction for fabricating any microelectronic or optoelectronic device on or in the material that is the subject of the authors' empirical studies. Heitz et al. thus provides no basis for the subject matter of claims 35-38, even if the fact is ignored that such claims are of dependent form under claim 1 and are thereby patentably differentiated over Heitz et al. on such basis alone.

The examiner in reference to Heitz et al. has contended (in paragraph 44, at page 7 of the Office Action) that it would have been obvious to determine optimum thickness, temperature and condition of delivery of layers involved. The relevance of this statement is not understood, since Heitz et al. provides no "starting basis" from which the applicants' claimed invention can be derived, by routine experimentation or otherwise.

The failure of Heitz et al. in this respect is illustrated, by way of example, in the statement at page 8 of the Office Action concerning claim 29, in which the examiner acknowledges that Heitz fails to

disclose a GaN material with background impurities including silicon and oxygen, in which iron dopant has a concentration greater than the total concentration of such silicon and oxygen, but then speculates that:

**"it would have been obvious that a background impurity of silicon and/or oxygen would render the gallium nitride layer non-insulating and therefore since Heitz teaches a semi-insulating [sic] the silicon and/or oxygen concentration in the background would be obviously low."**

Such rejection of claim 29 therefore is based on a hypothetical importation into GaN material of the silicon and oxygen as background impurities, which are conceded to be absent from Heitz et al., but which somehow, despite the absence of any disclosure in Heitz et al., are put into the material and then somehow, again without basis in the reference, compensated by iron doping.

Such rejection thus is based on a string of speculative hypotheses that are fully outside the scope of any reasonable interpretation of the Heitz et al. reference. There is simply no basis on which one of ordinary skill in the art, reading Heitz et al. for what it fairly discloses, would in any straightforward, logical manner extrapolate the compositional teachings of Heitz et al. to include components which are nowhere mentioned in such reference!

Concerning claim 30, the examiner has rejected such claim over Heitz et al. in view of Heikman et al. "Claim 30 recites a doping concentration of iron in a range of from about  $3 \times 10^{16}$  atoms per cubic centimeter to about  $7 \times 10^{17}$  atoms per cubic centimeter, as determined by SIMS. The examiner has contended that it would have been obvious to one of ordinary skill in the art to incorporate the doping range of Heikman et al. into the Heitz et al. "semiconductor device."

Heikman et al. contains no teaching or suggestion of a large-area, single-crystal GaN. It again is pointed out that the term "large area" requires a transverse dimension (diameter or diagonal, depending on the shape of the wafer; see paragraph [0022] of the present application) of at least 25 mm. The single transverse dimension disclosed in Heikman et al. is the reference dimension of 100 micrometers associated with the dimensional bar in Fig. 2 of the article. Such reference dimension, as applied to the overall height and width of the micrograph, indicates that each of the height and width dimensions of the illustrated section of GaN in Fig. 2 of the Heikman et al. is between 200 and 300

micrometers. The minimum transverse dimension required by applicants' claims (25 mm) is 25,000 micrometers, many orders of magnitude above the dimension illustrated in Fig. 2 of Heikman et al.

Further, the surface of the GaN material shown in Fig. 2 of Heikman et al. is highly cracked and discontinuous in character across the full extent of such surface, and such surface in fact is described by Heikman et al. as a "rough surface." This surface of Heikman et al.'s material does not give any indication of being a single crystal material - the extremely rough, cracked, discontinuous character of the material in fact appears more consistent with a polycrystalline or even semi-amorphous material. There is no mention in Heitz et al. of any "single crystal" material.

Still further, the film thickness disclosed in Heikman et al. for the GaN material of such reference is 2.6 micrometers, of which only the first 0.3  $\mu$ m of the film is doped. See the abstract of Heikman et al. See also the Fig. 3 SIMS profile in Heikman et al., which shows a film depth of 1  $\mu$ m. This is to be contrasted with the disclosure of the applicants' GaN material in paragraph [0022] of the present application, where it is stated that "[T]he thickness dimension [of applicants' GaN material] desirably is at least 300 micrometers." This 300+ micrometers thickness is claimed in a number of the pending claims of the present application. Again, such dimensional characteristic of applicants' GaN material is orders of magnitude above the thickness disclosed in Heikman et al.

Moreover, the resistivity values given in Heikman et al. are sheet resistivities, and not bulk resistivities; there is no basis for viewing Heikman et al. as in any way describing or suggesting applicants' claimed GaN material.

The foregoing reflects the fact that the disclosure in Heikman et al. is fundamentally deficient in relation to the disclosure of GaN material in Heitz et al., and there is nothing in their combination that would yield, motivate or extrapolate to applicants' claimed GaN material. The combination of Heitz et al. and Heikman et al. does not yield large-area GaN, and it does not yield a single-crystal GaN.

Concerning claims 14, 39, 40 and 41, the same have been rejected as unpatentable over Heitz et al. in view of Cuomo et al., on the stated basis that "it would have been obvious to one of ordinary skill in the art to incorporate the limitations of Cuomo into the Heitz semiconductor device, because bulk materials can be used as substrates upon which microelectronic and optical devices are fabricated."



The Cuomo reference teaches use of  $M^{III}N$  columns for growth of continuous, low defect-density GaN layer that are n-type or p-type (see Cuomo et al., at column 14, lines 22-27), but it does not in any way teach or suggest the formation of semi-insulating gallium nitride, as required by the claims of the present application. Cuomo et al. at column 14, lines 22-27 merely teaches that:

**"During their respective growth steps, columns 14, CEO layer 20, and/or bulk  $M^{III}N$  layer 30 can be doped by conducting conventional doping methods, such as by introducing dopant-containing gases into the reaction chamber under controlled conditions. Multiple or alternating layers of dopants can be added to form electronic devices or components such as, for example, p-n junctions."** Cuomo et al., column 14, lines 22-27

Thus, the only teaching of Cuomo et al. involving doping is a teaching to form PN junctions. PN junctions comprise p-type semiconductors, i.e., semiconductors in which the concentration of holes is much higher than the concentration of electrons, and n-type semiconductors, i.e., semiconductors in which the concentration of electrons is much higher than the concentration of holes. Neither of such types of semiconductor is semi-insulative in character. There is thus an absence of any mention of, or suggestive basis for, semi-insulative material in the disclosure of Cuomo et al.

Accordingly, not only does Cuomo et al. fail to remedy the multiple deficiencies of Heitz et al., Cuomo et al. in fact teaches away from any provision of semi-insulative material, since the teachings of Cuomo et al. are directed to doped material that is either p-type semiconductor or n-type semiconductor, and there is not even a hint of semi-insulative material anywhere in the disclosure of Cuomo et al.

Further, there is no motivation for combining the disparate disclosures of Heitz et al. and Cuomo et al., since Heitz et al. is simply concerned with photoluminescence studies ("[I]n this paper we report a comprehensive PLE investigation"-Heitz et al., at page 4382) and is fundamentally deficient in providing any basis for applicants' claimed invention. Cuomo et al. is concerned with columnar growth of Group III-nitride, as a platform for growth of bulk materials, and such reference is wholly devoid of any teaching, suggestion or other basis for semi-insulative GaN material.

In consequence, the hypothetical combination of the Heitz et al. and Cuomo et al. references that has been suggested in the Office Action derives solely from an improper hindsight attempt to reconstruct

the present invention, and therefore does not provide a proper basis for contending that the subject matter of claims 14 and 39-41 is obvious.

Based on all of the foregoing, the applicants respectfully request the Examiner to reconsider, and upon reconsideration to withdraw, the rejections of claims 1-41.

**Request for one-month extension of time under 37 CFR 1.136**

Request hereby is made under the provisions 37 CFR 1.136 for a one-month extension of the term for response set in the May 9, 2005 Office Action, extending the deadline to response from August 9, 2005 to September 9, 2005. The fee of \$120 specified in 37 CFR 1.17 (a) (1) for such one-month extension of time hereby is authorized be charged to the credit card specified in the enclosed Credit Card Authorization Form. Authorization also is hereby given to charge the amount of any deficiency to Deposit Account No. 08-3284 of Intellectual Property/Technology Law.

\*\*\*\*\*

If any issues remain outstanding, incident to the formal allowance of the application, the Examiner is requested to contact the undersigned attorney at (919) 419-9350 to discuss same, in order that this application may be allowed and passed to issue at an early date.

Respectfully submitted,



Steven J. Hultquist  
Registration No. 28021  
Attorney for Applicants

INTELLECTUAL PROPERTY/  
TECHNOLOGY LAW  
P.O. Box 14329  
Research Triangle Park, NC 27709  
Telephone: (919) 419-9350  
Fax: (919) 419-9354  
Attorney Ref: 4241-661

**The Office is hereby authorized to charge any fees determined to be properly payable for entry of this Response, to Deposit Account 08-3284 of Intellectual Property/ Technology Law.**